LOAN COLLECTION OF SCIENTIFIC APPARATUS

SECTION—MECHANICS

PRIME MOVERS [1]

THE subject on which I have now the honour to address you, the subject which is to occupy our attention to-day, is that of prime movers, that is to say, we are about to consider that class of machines which, to use the words of Tredgold, "enable the engineer to direct the great sources of power in nature for the use and convenience of man."

Although machines of this kind are, in truth, mere converters or adapters of extraneous forces into useful and manageable forms, and have not any source of life, power, or motion, in themselves, nevertheless they impress us with the notion of vitality; and it is difficult to regard the revolving shaft of a water-wheel or turbine, set in motion by some hidden stream, or to gaze upon the steam-engine actuated by an unseen vapour, without, as I have said, the idea being raised in our minds that the machines on which we are looking are really endowed with some kind of life.

The invention of such machines marks a very great step in the progress of mechanical science in the world, as it commences an era distinct from that in which mere machines to be acted on by human or animal muscular force were alone in existence. Machines such as these, highly useful as they may be, are, after all, only tools or implements more or less ingenious and more or less complex.

Mankind could not have been very long upon the earth before they must have found the need and must have discovered the utility of some kind of tool or implement; they must soon have found that the direct action of the power of the arm, which was not enough by itself to break up some obstacle, became sufficient if that action were applied by the wielding of a heavy club, or through the putting into motion of a large stone, and thus the hammer or its equivalent must have been among the earliest of inventions. Such an implement must soon have taught its users that muscular force could be exercised through a considerable space, could be stored up, and could be delivered in a concentrated form by a blow.

Similarly it could not have been long before it must have been found that to raise water in the hollow of the hand by repeated efforts was not so convenient a mode as to raise it in a bent leaf or in a shell, and in this way another implement would speedily be invented. We might pursue this line of speculation, and doing so we should readily arrive at the conclusion that (without attributing to the early inhabitants of the earth any profound acquaintance with mechanics) the hammer, the lever, the wedge, and other simple tools and utensils, must soon have come into existence; and we should also be led to believe that when, even with the aid of tools such as these, a man singly could not accomplish any desired object, the expedient of combining the power of more than one man to attain an end would soon be thought of, and that the requisite appliances, such as large beams used as levers, numerous ropes (which must very early in the history of the world have been twisted from filaments) and matters of that kind, would come into use. For a corroboration of this view, if one were wanted, the fact may be cited that on the discovery of any isolated savage community it always is found to have advanced thus far in mechanical art.

But passing from such machines as these, which are rather of the character of tools and implements, than machines, as we now popularly use the word, one knows that even complicated mechanism for the purpose of enabling muscular force to be more readily applied, is of very ancient date. On this point I will quote from only one book, that is the Bible, where, at the 10th and 11th verses of the 11th chapter of Deuteronomy, a statement is made clearly indicating that in Egypt irrigation was carried on by some kind of machine worked by the foot; whether the treadwheel with water-buckets round about it mentioned by Vitruvius, or whether the plank-lever with a bucket suspended at one end and worked by the labourer running along the top of the lever to the other end (an apparatus even now used in India), we do not know; but that it was some machine worked by the foot is clear, the statement being that when the Israelites had reached the Promised Land they would find it was one abounding in streams, so as to be naturally watered, and that it would not require to be watered by the foot as in Egypt. Again, in Chronicles it is related that King Uzziah loved husbandry, and that he made many engines, unhappily not in connection with agriculture, but for warlike purposes, "to shoot arrows and great stones withal." Further, in the 7th chapter of the Book of Job, we have the comparison of the life of man passing away swifter than a weaver's shuttle; this points unmistakeably to the fact that there must in those days have been in existence a loom capable of weaving fabrics of such widths that the shuttle required to be impelled with a speed equal to a flight from one side of the fabric to the other, and no doubt such a fabric must have been made in a machine competent at last to raise and depress alternately the halves of the warp threads. The potter's wheel also is frequently mentioned in the Bible.

Such instances as these are sufficient to show that considerable progress must have been made in the very earliest days of history in the construction of machines whereby muscular force was conveniently applied to an end; but if we leave out of account, as we fairly may, the action of the wind in propelling a boat by sails, and the action of the wind in winnowing grain, I think we shall be right in considering that in the times of which I have been speaking there did not exist any machine in the nature of a power-giver or prime mover.

Doubtless the want of a greater force than could be obtained from the muscles of one human being must have soon made itself felt; and intelligent men, conscious of their own ability and of their mental power of directing a large amount of work, must have been grieved at finding the use of that power circumscribed by the limited force of their own bodies, and therefore early in the world's history there must have been the attempt, by the offer of some consideration or reward, to induce other men (men gifted with equal or stronger muscles, but probably not with equal minds) to work under the directions of these men of superior intelligence. But when such aid as this became insufficient, the way in which, in all probability, the people of those days endeavoured to satisfy the further demand would be to make captives of their enemies and to reduce them into a state of bondage, to grind at the mill, to raise water, or, yoked by innumerable cords and beams to some heavy chariot or sledge, to draw along the huge blocks required in the foundations of a temple, or for the building of a pyramid, or to act in concert on the many oars of a galley, although by what means this last-named operation was performed is not very clear. Doubtless under this condition of things there must have been an amount of human suffering which is too frightful to be contemplated.

Such machines as those to which I have called attention could not have been invented and brought into use without the exercise of much mechanical skill; but considerable as this skill must have been it had never originated a prime mover; it had given no source of power to the world, but had left it dependent on the muscular exertions of human beings and of animals.

Great, then, was the step, and a most distinct era was it in mechanical science, when for the first time a prime mover was invented and a machine was brought into existence which, utilising some hitherto disregarded natural force, converted it into a convenient form of power, by which as great results could be obtained as were obtainable by the aggregation of a large number of human beings, and could be obtained without bondage and without affliction.

There are probably few sights more pleasing to one who has been brought up in factories than to watch a skilful workman engaged in executing a piece of work which requires absolute mastery over the tools that he uses, and demands that they should have the constant guiding of his intelligent mind. Handicraft work of such a kind borders upon the occupation of the artist, and to see such work in the course of execution is, as I have said, a source of pleasure. But when descending from this the work becomes more and more of the character of mere repetition, and when it is accomplished by the aid of implements which, from their very perfection require but little mind to direct them, and demand only the use of muscle, then, although the labour, when honestly pursued, is still honourable, and therefore to be admired, there comes over one a feeling of fear and of regret that the man is verging towards a mere implement. But when one sees, as I have seen in my time, in England, and as I have seen very recently on the Continent, men earning their living by treading within a cage to cause it to revolve and thereby to raise weights, an occupation demanding no greater exercise of intelligence than that which is sufficient to start, to stop, and to reverse the wheel at the word of command, one does indeed regret to find human beings employed in so low an

[1] Address delivered by F. J. Bramwell, C.E., F.R.S., one of the vice-presidents of the Section, May 25.

occupation, an occupation that places them on a level with the turnspit. It is one which is most properly meted out in our prisons as a punishment for crime, accompanied, however, with the degradation that the force exerted shall be entirely wasted in idly turning a fan in the free air, and thus the prisoner, in addition to the fatigue of his body, undergoes the humiliation of, as he expresses it, "grinding the wind."

If they played no other part than that of relieving humanity from such tasks as these, prime movers would be machines to be hailed.

True it is that the labourers who were thus relieved would not thank their benefactors, and indeed so far as the individuals subjected to the change were concerned they would have cause not to thank them, because they having been taught no other mode of earning a livelihood, and finding the mode they knew set on one side by the employment of a prime mover, would be at their wit's end for a means of subsistence, and would be experiencing those miseries which are caused by a state of transition. But in some way the men of the transition state must be relieved, and in the next generation, it no longer being possible to subsist by such wholly unintelligent labour, the energies of their descendants would be devoted to gaining a livelihood by some occupation more worthy of the mind of man.

Early prime movers, from their comparatively small size, probably did little more than thus relieve humanity; but when we come to consider the prime movers of the present day, by which we are enabled to contain within a single vessel and to apply to its propulsion 8,000 indicated horse-power, or an equivalent of the labour of nearly 50,000 men working at one time, we find that the prime mover has another and most important claim upon our interest: it enables us to attain results that it would be absolutely impossible to attain by any aggregation of human or other muscular effort, however brutally indifferent we might be to the misery of those who were engaged in that effort.

Excluding from our consideration light and even electricity, as not being, up to the present time, sources of power on which we rely in practice, there remain three principal groups into which our prime movers may be arranged, viz., those which work by the agency of wind, those which work by the agency of water, and those which work by the agency of heat. But some of these great groups are capable of division, and indeed demand division into various branches.

Water power may be due to the impact of water, as in some kinds of water-wheels, turbines, and hydraulic rams, or to water acting as a weight or pressure, as in other kinds of water-wheels, and in water-pressure engines; or to streams of water inducing currents, as in the case of the jet-pump, and of the "Trombe d'eau," or to its undulating movements, as in ocean waves. The ability of water to give out motive force may arise from falls, from the currents of rivers, from the tides, or, as has been said, from the oscillation of the waves.

Prime movers which utilise the force of the wind are few in number and in all cases act by impact.

As regards those prime movers which work by the aid of heat, we may have that heat developed by the combustion of fuel, and being so developed applied to heating water, raising steam, and working some of the numerous forms of steam-engines; or, as in the case of the Giffard injector, performing work by induced currents, by the flow of steam; or we may have the heat of fuel applied to vary the density of the air, and thus to obtain motion as by the smoke-jack; or the fuel may be employed to augment the bulk and the pressure of gases, as in the numerous caloric engines; or we may have heat and power developed in the combustion of gases, as in the forms of gas-engines; or in the combustion of explosives, as in gunpowder, dynamite, and other like materials, used not only for the purposes of artillery and of blasting, but for actuating prime movers in the ordinary sense of the word.

Again, we may have the heat of the sun applied through the agency of the expansion of gases or surfaces to the production of power, as in the sun-pumps of Solomon de Caus and of Belidor, and as in the sun-engine of Erricsson. Finally, we may have the sun's rays applied direct, as in the radiometer of Mr. Crookes.

A consideration of the foregoing heads, under which prime movers range themselves, will speedily bring us to the conclusion that the main centre of all mechanical force on this earth is the sun. If the prime movers be urged by water, that water has attained the elevation from which it falls, and thus gives out power by reason of its having been evaporated and raised by the heat of the sun. If the power of the water be derived from the tidal influence, that influence is due to the joint action of the sun and the moon.

If the prime mover depend upon the wind for its force either directly, as in windmills, or indirectly, as in machines worked by the waves, then that wind is caused to blow by variations of temperature due to the action of the sun. If the prime mover depend upon light or upon solar heat, as in the case of the radiometer and of the sun engine, then the connection is obvious; but if the heat be due to combustion, then the fuel which supports that combustion is, after all, but the sun's rays stored up. If the fuel be, as is now sometimes the case, straw or cotton stalks, one feels that they have been the growth of the one season's effect of the sun's rays. If the fuel be wood, it is equally true that the wood is the growth of a few seasons' exercise of the sun's rays, but if it be the more potent and more general fuel coal, then, although the fact is not an obvious one, we know that coal also is merely the stored up result of many ages exercise of solar power.

And even in the case of electrical prime movers, these depend on the slow oxidation, that is burning, of metal which has been brought into the metallic or unburnt state from the burnt condition (or that of ore) by the aid of heat generated by the combustion of fuel.

The interesting lecture-room experiment with glass tubes charged with sulphide of calcium, or other analogous sulphides, makes visible to us the fact that the sun's rays may be stored up as light; but that they are as truly stored up (although not in in the form of light) in the herb, the tree, and the coal we also now know; and we appreciate the far-seeing mind of George Stephenson who astonished his friend by announcing that a passing train was being driven by the sun. We know that Stephenson was right, and that the satirical Swift was wrong when he instanced as a type of folly the people of Laputa engaged in extracting sunbeams from cucumbers. The sunbeams were as surely in the cucumbers as they are in the sulphide of calcium tubes, but in the latter case they can be seen by the bodily eye, while in the former they demand the mind's eye of a Stephenson.

Athough the sailing of ships and the winnowing of grain must from very early time have made it clear that the wind was capable of exercising a moving force, nevertheless, being an invisible agent, it is not one likely to strike the mind as being fit to give effect to a prime mover, and therefore it is not to be wondered at that prime movers actuated by water are those of which we first have any record, unless indeed the toy steam-engine of Hiero may be looked upon as a prime move anterior to those urged by water. It would appear that in the reign of Augustus water-wheels were well known, for Vitruvius, writing at that time, speaks of them as common implements, but not so common as to have replaced the human turnspit, as we gather from his writings that the employment of men within a treadwheel was still the most ordinary mode of obtaining a rotary force. It would seem, however, that water-wheels driven by the impact of the stream upon pallet boards were employed in the time of Augustus not merely to raise water by buckets placed about the circumference of the wheels, but also to drive millstones for grinding wheat, and Strabo states that a mill of this kind was in use at the palace of the King of Pontus.

(*To be continued.*)

SCIENTIFIC SERIALS

Poggendorff's Annalen der Physik und Chemie, No. 2, 1876.—In the opening paper of this number Dr. König describes a series of researches in which he sought to study more closely the phenomena which occur when two sets of sound-waves meet in air; using sources of sound that were entirely isolated and could not act directly on each other, nor in common on a third body; he also chose sources that would give as simple tones as possible. The paper is in four parts, treating, severally, of primary beats and beat-tones, secondary beats and beat-tones, difference-tones and summation tones, and the nature of beats and their action, compared with the action of primary impulses. On the last head he finds, *inter alia*, that beat-tones cannot be explained by the cause of difference and summation tones, and that the audibility of beats depends only on the number and intensity of the primary tones, not at all on the width of the interval. The number of beats and primary impulses with which both may be